Pressure and temperature measurements with a dual-luminophor coating

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Abstract:
Data reduction requirements for dual-luminophor pressure/temperature sensiti (P/TSP) are explored through the use of principal component analysis. The dual-luminophor coating contains one luminophor which primarily responds to temperature and one which responds to both temperature and pressure. The an indicates that a two-factor reduced order model based on two fundamental spe represents the majority of the luminescence response but cannot properly acco mutual interaction effects between the luminophors. The inclusion of a third fac appears to sufficiently model the mutual interaction effects. This work indicates P/TSP data reduction procedures based on principal component analysis are pr improving the accuracy of the measurements. The potential to remove the requ a wind-off reference image and to reject high frequency noise is also indicated.

Index Terms:
wind tunnels aircraft testing principal component analysis data reduction tempe measurement pressure measurement radiation quenching pressure sensors tem sensors photoluminescence dual-luminophor coating temperature measuremen measurement data reduction requirements pressure/temperature sensitive pain component analysis two-factor reduced order model luminescence response mu interaction effects measurement accuracy high frequency noise rejection oxyge quenching wind tunnel testing

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An optical technique for detecting fatigue cracks in aerospace structures

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Abstract:
The development of a field-deployable non-intrusive optical-based crack-detect measurement system based on temperature-sensitive-paint (TSP) technology i described. The TSP developed is based on a platinum porphyrin immobilized in sol-gel-derived thin film. For this test, the TSP is deposited on top of an alumin that is then subjected to dynamic fatigue through the use of an electrodynamic Detection of cracks in the aluminum is accomplished by monitoring the change surface temperature of the plate as it was excited at its resonant frequency. Vis and measurement of the cracks is easily accomplished in near real time using t method. Finally, this method is compared with conventional thermography, and results indicate that for aluminum, the surface-temperature change was below resolution of conventional instrumentation.

Index Terms:
crack detection infrared imaging fatigue cracks aerospace testing aerospace str fatigue crack detection optical technique field-deployable temperature-sensitive platinum porphyrin sol-gel film immobilized dynamic fatigue

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Application of temperature sensitive paint for detection of boundary layer trans

- Popernack, T.G. Owens, L.R. Hamner, M.P. Morris, M.J.
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Abstract:
Temperature sensitive paint systems exploit the variation in convective heat tra
associated with changes from laminar to turbulent flow for detection of bounda
transition. For this detection technique, it is important for wind tunnel models t
slow thermal response relative to convection heat transfer. Wind tunnels that c
rapid changes in freestream temperature can create a model thermal response
temperature sensitive paint to indicate transition. Numerical heat transfer simu
provide acceptable estimates to assess test techniques and model thermal char
Data are presented to substantiate that the desired test condition could be achi
period of time sufficient to document the boundary layer state.

Index Terms:
boundary layers wind tunnels forced convection laminar to turbulent transitions
flow aerodynamics temperature sensitive paint boundary layer transition conve
transfer wind tunnel models thermal response freestream temperature heat tra
simulations test techniques boundary layer state

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TSP

TEMPERATURE SENSITIVE PAINT

High resolution, non-intrusive measurement temperature and heat transfer using temper sensitive paint have been demonstrated by L Campbell. A typical TSP consists of the lumin molecule and an oxygen impermeable binde basis of the temperature sensitive paint met the sensitivity of the luminescent molecules thermal environment. The luminescent mole placed in an excited state by absorption of a The excited molecule deactivates through th emission of a photon. A rise in temperature luminescent molecule will increase the proba that the molecule will return to the ground s radiationless process. This process is known thermal quenching and is the basis of tempe sensitive paint. The temperature of the pain surface can be measured by detecting the fluorescence intensity I(T) of the luminescen

The luminescent intensity of the temperatur sensitive paint at a given point is not only a of temperature.For practical applications of T spatial variations in illumination, paint conce paint layer thickness, and camera sensitivity result in a variation in the detected luminesc intensity from the test surface. These spatia variations are eliminated by ratioing the lum intensity of the paint at the unknown test co (I_T) with the luminescent intensity of the pai known reference condition (I_{ref}, T_{ref}).

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Fundamentals of Pressure and Temperature Sensitive Paints

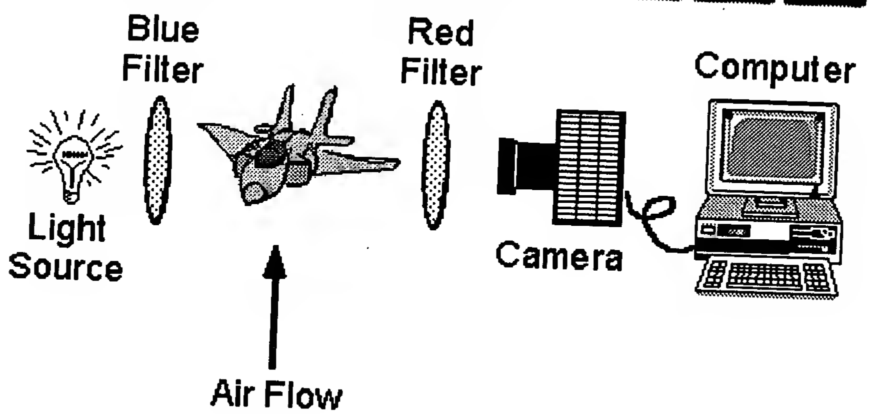

Figure 1. Typical Pressure or Temperature Sensitive Paint (PSP or TSP) experimental arrangement

Pressure and Temperature Sensitive Paints (PSP & TSP) are luminescent surface coatings for which the luminescence intensity is related to the surface pressure and temperature. PSP consists of an oxygen permeable polymer binder in which a luminescent dye is dispersed. The dye is excited by absorbing light (generally UV or blue) and relaxes by emitting red shifted light. An alternate decay process is through the interaction of the dye with an oxygen molecule (called oxygen quenching). As the pressure above the layer increases, the oxygen concentration within the layer will increase and the luminescence intensity will decrease.

The luminescence intensity of the dyes is also temperature dependent, as is the mass diffusivity of the polymer binder. These two effects cause PSP coatings to also be sensitive to temperature. To make a temperature sensitive paint (TSP), you simply disperse the dye in an oxygen impermeable binder such as epoxy. Dual purpose coatings for simultaneous pressure and temperature measurements are possible and are currently being developed by our group.

Figure 1 shows a typical experimental arrangement for either PSP or TSP. An illumination source is used to excite the paint layer coated on the model (in this case and aircraft in a wind tunnel). Common illumination sources are filtered tungsten-halogen lamps (450 nm) or the blue line of an argon-ion laser (488 nm). The red shifted luminescence is then measured with a camera/filter (600-650 nm) arrangement. The camera can be either a film based camera or a cooled CCD camera. For land based applications, the cooled CCD is generally more accurate and easier to use, while flight testing applications often require the film based method.

A schematic of the actual PSP layer is shown in Figure 2 for isothermal, steady state conditions. Temperature variations across the surface will introduce errors into the measurements. Additionally, unsteady pressures introduce problems since the oxygen concentration across the layer is no longer uniform due to finite diffusion times. A TSP layer would be similar except that the binder would be oxygen impermeable such that the oxygen concentration within the layer would be zero.

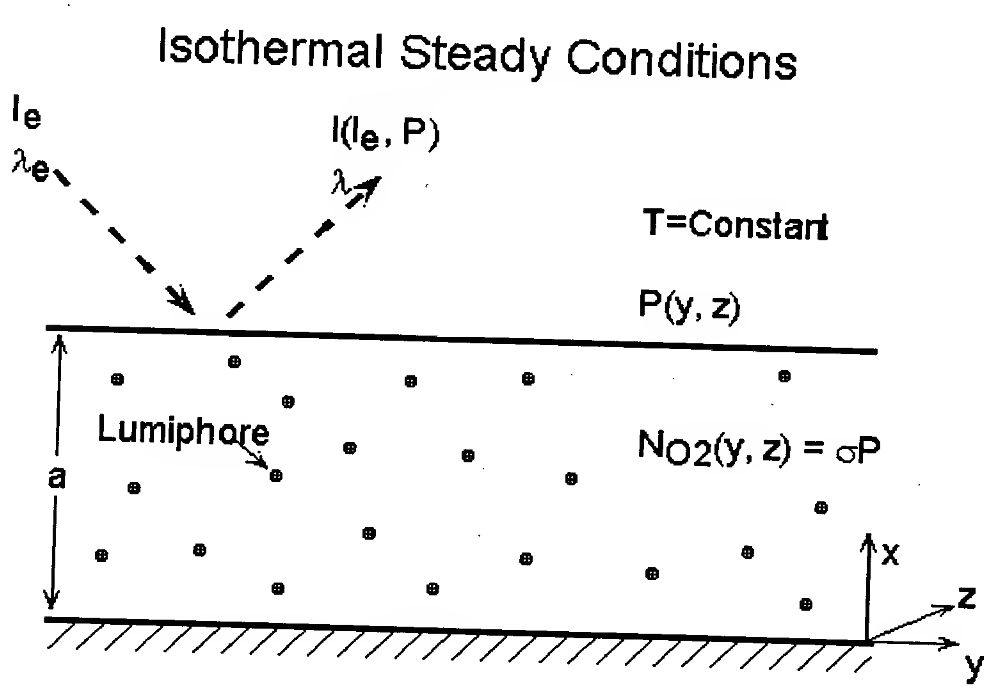

Figure 2. Enlargement of a PSP coating. The layer is held at constant temperature and pressure

Opportunities for Graduate Study

Contact Dr. Carroll (bfc@aero.ufl.edu) if you are interested in research areas described in this web site. Graduate assistantships and scholarships are available for qualified applicants.

TEMPERATURE-SENSITIVE PAINTS

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Introduction

In recent years, new techniques based on luminescence quenching have b developed for measuring temperature distributions on wind tunnel mode new sensors are called temperature-sensitive paint (TSP). By comparison conventional techniques such as thermocouples and pressure taps, the TS techniques provide a way to obtain simple, inexpensive, full-field measu of temperature with much higher spatial resolution. TSP incorporates lum molecules in a paint which can be applied to any aerodynamic model sur Figure 1 shows a schematic of a paint layer incorporating luminescent mo

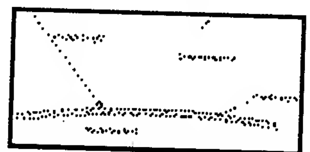

Figure 1: Schematic of TSP/PSP Layer

The paint layer is composed of luminescent molecules and a polymer bin material which can be dissolved in a solvent. The resulting paint can be a a surface using a brush or sprayer. As the paint dries, the solvent evapor leaves behind a polymer matrix with luminescent molecules embedded in of the proper wavelength to excite the luminescent molecules in the pain directed at the model, and luminescent light of a longer wavelength is e the molecules. Using the proper filters, the excitation light and luminesc emission light can be separated and the intensity of the luminescent ligh determined using a photodetector. Through the photo-physical processes thermal- and oxygen-quenchings, the luminescent intensity of the paint e related to temperature. Hence, from the detected luminescent intensity temperature can be determined. Figure 2 shows a typical surface temper map for supersonic flow around a cylinder with a turbulent boundary laye

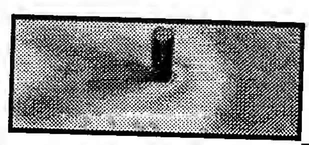

Figure 2 Surface temperature map for supersonic flow around a cylinde turbulent boundary layer at Mach = 2.5.

These TSP techniques have been under development at Purdue University

Questions about the OEL and related courses should be directed to Professor Peter Bryanston-Cross
Any questions or comments about this web site should be directed to the OEL Webmaster
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Paints contain 4 basic ingredients, pigment, binder, solvent, and additives. Pigments give the paint color and hiding ability, and some provide stain blocking and corrosion resistance. Titanium Dioxide is the most commonly used hiding pigment. Clays, talc, and other materials are used as extender pigments. The binder is the resin that holds the dried paint together. Typical resins are acrylic, vinyl acrylic, alkyd, urethane, and epoxy. The binder is what usually determines the resistance characteristics of the paint, including such things as scrubbability, fade resistance, flexibility, etc. The binder also helps the paint adhere to a surface. Solvents are used to disperse or dissolve the solids in the paint and allow it to be applied to a surface. They affect application characteristics, dry time, and, in two component materials, the rate of chemical reaction between the two parts. Additives are used to improve such things as mildew resistance, thickness, in-can stability, and stain blocking ability to name a few.